Sensors Development for IPP Robotic Vehicle

Mark Garrett / Michael Hassard

Sandia National Laboratories
msgarre@sandia.gov
505-845-3356
mhassar@sandia.gov
505-844-8610
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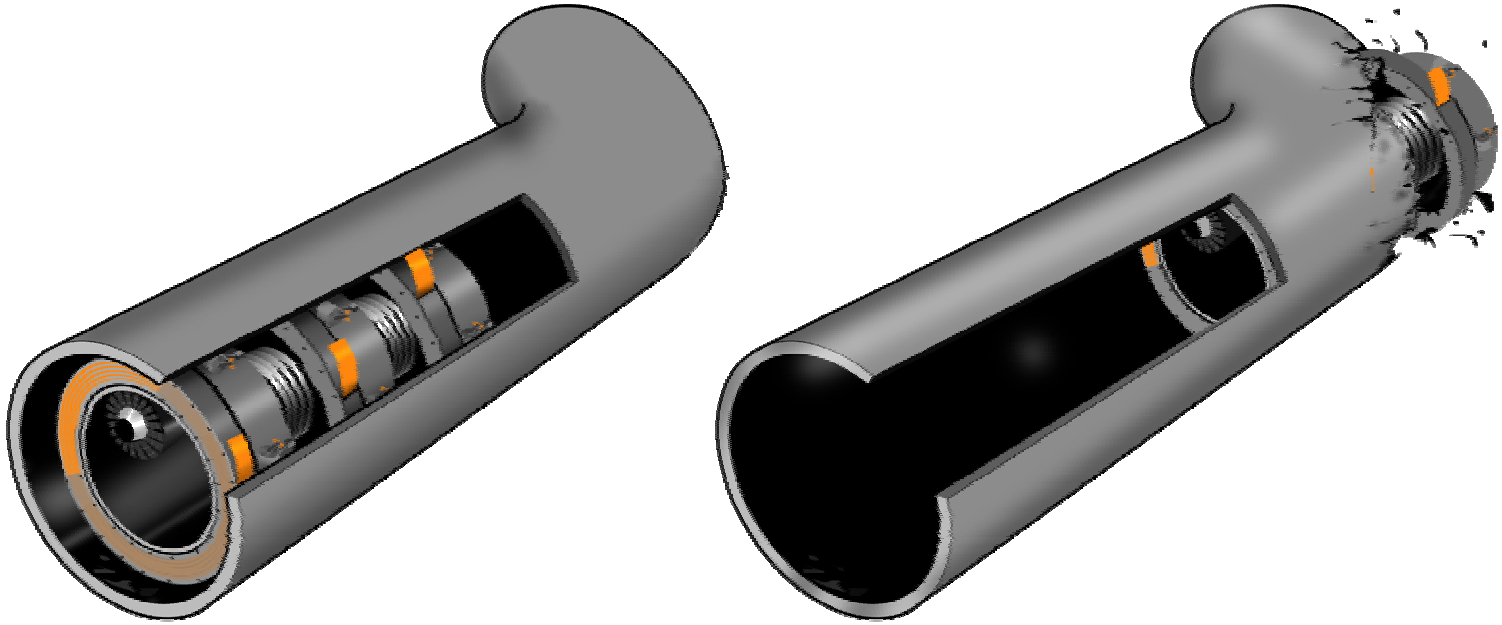
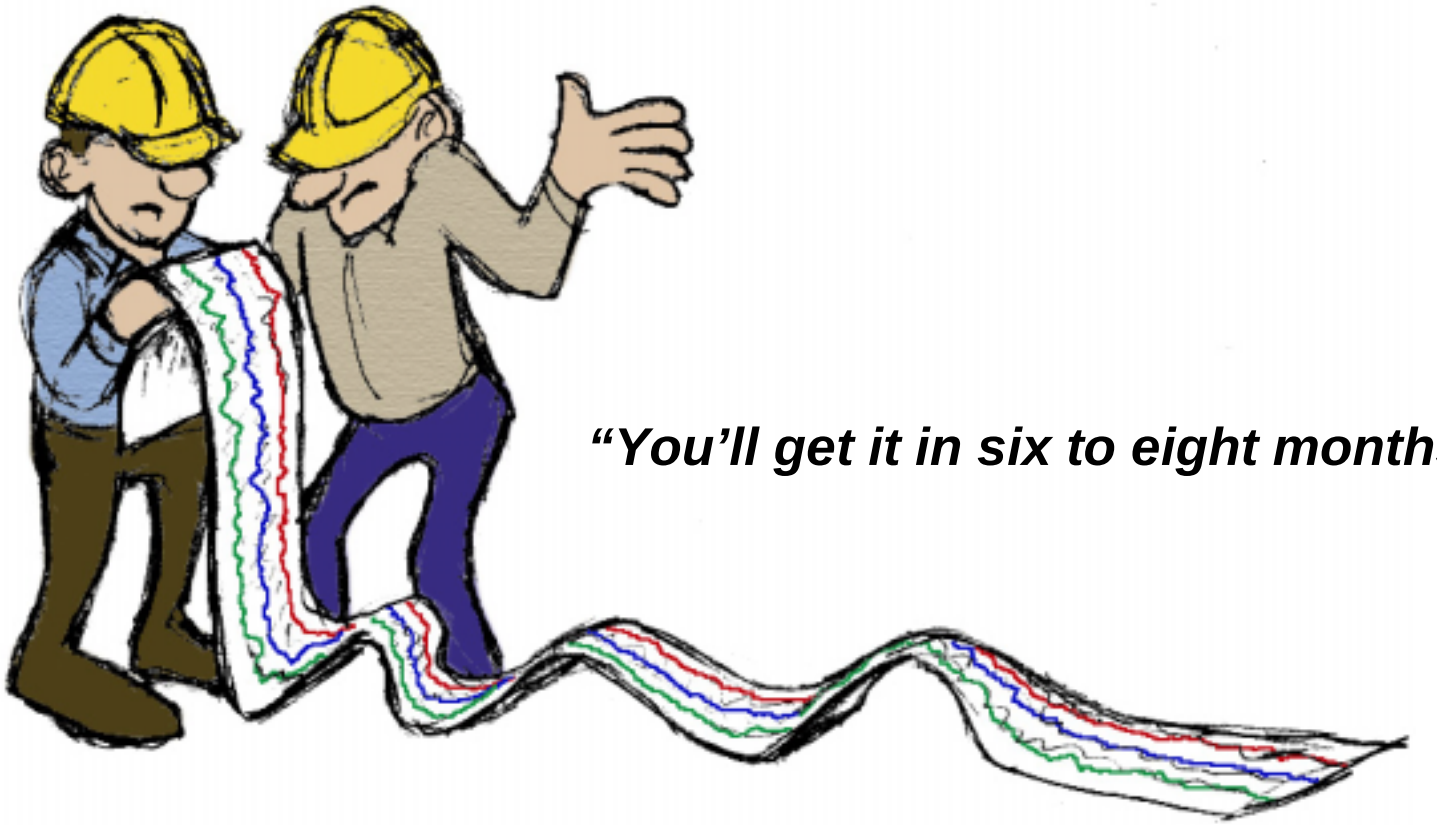
The Problem . . .



Old Method



“You’ll get it in six to eight months.”

Effective internal natural gas pipeline inspection requires two basic things.

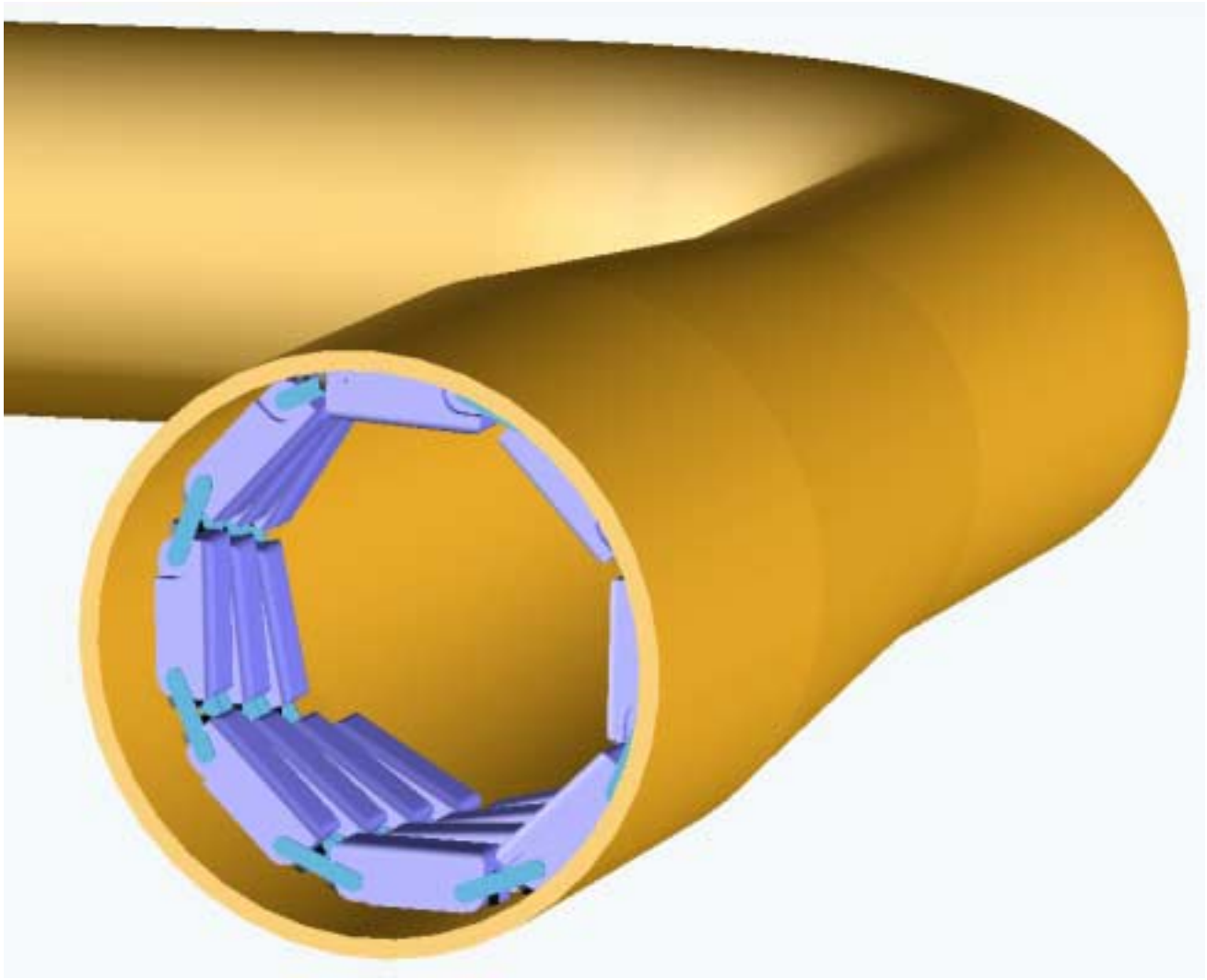
A vehicle that can access all areas and locations

With sensor technology that can quickly identify, quantify, and accurately locate all ‘problem’ areas.

Sandia's Task

- Develop a self-propelled, adaptable geometry, robotic vehicle that can dwell and maneuver within the pipe.
- Sensor systems must be compatible with this unique mobility and will be designed / evaluated for their:
  - Effectiveness
  - Compactness
  - Power Requirement
  - Sensitivity to internal environment (noise).
- Apply or develop sensors for locating and assessing the severity of pipeline defects / damage including:
  - Corrosion
  - Cracks
  - Dents
  - Other pipe defects.

. . . The Solution



New Method

"Five minutes ago we found . . ."

We are new to the pipeline inspection business, and so, research at Sandia National Laboratories has begun with finding out what is being used successfully in the Pipeline Pigging industry today. What methods have been abandoned as unfeasible and why.

- **Gas Technology Institute**
- **Keifner and Associates**
- **Duke Energy**
- **API**
- **DoE / DoT**
- **Battelle**
- **ASNT Materials Evaluation**
- **Jentek Sensors**
- **Southwest Research Institute**
- **NETL**
- **Nautronix**
- **British Gas**
- **Cambridge University**
- **Dozens of others…**

We've seen the tip of the Iceberg from these references.

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Research Road Blocks

- **Proprietary concerns and maintaining a competitive advantage limits amount, detail, and quality of information available from industry sources.**
- **We would like to obtain more information and cooperation from industry regarding current R&D of sensor technologies.**
- **SNL would rather team than compete! Being a National Laboratory prohibits us from competing with industry.**
- **SNL would prefer to add or create new technologies rather than waste resources re-inventing existing technology.**

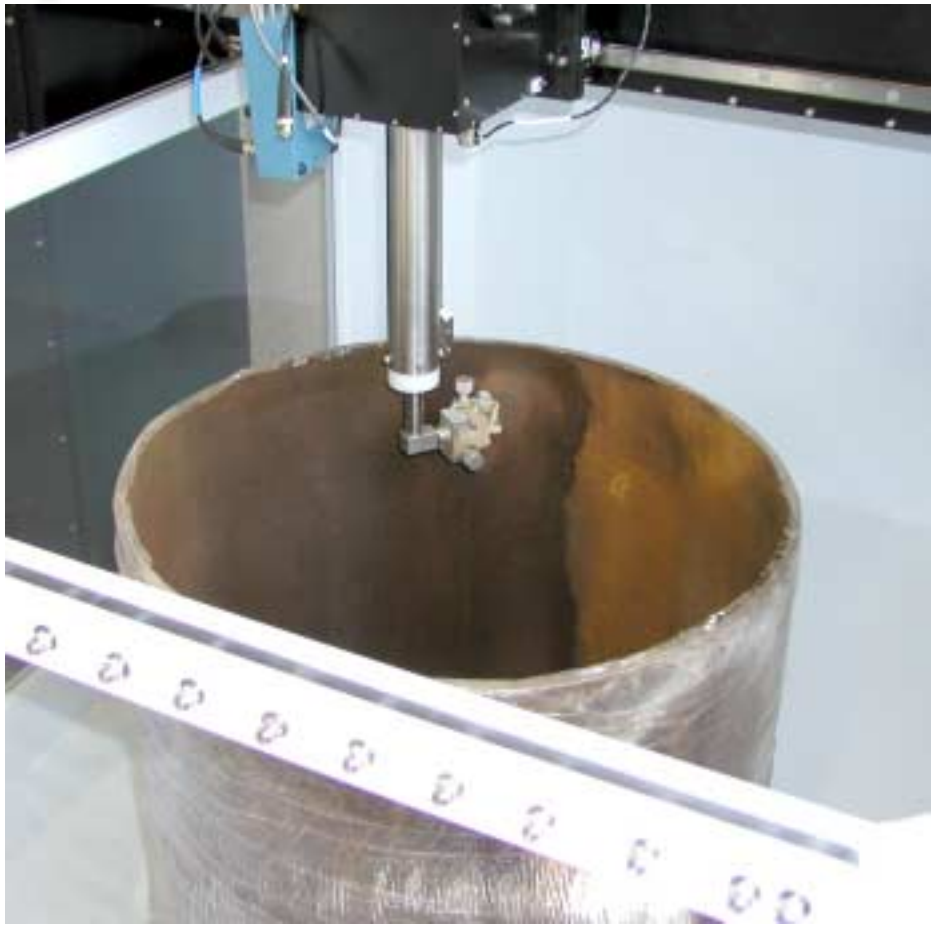
Sensor Evaluations

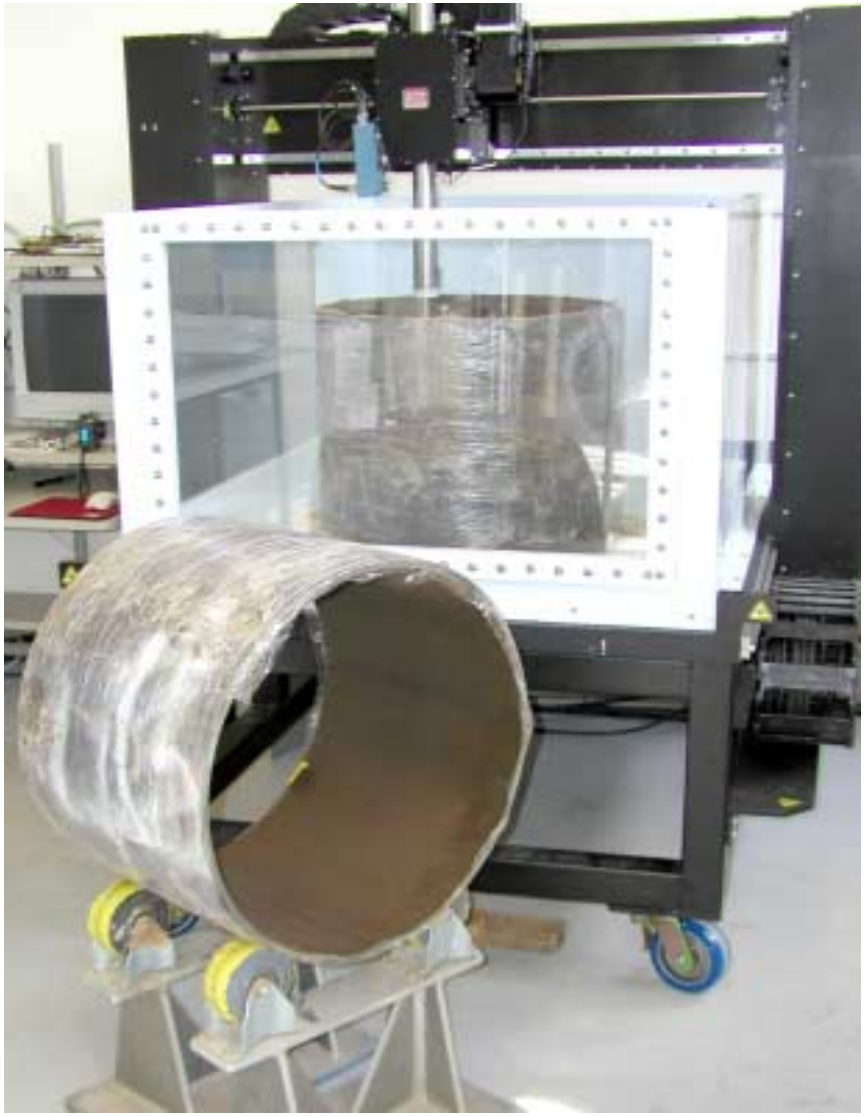
In order to evaluate and develop sensor technologies a lab based scanning platform is needed. This platform must be easily adapted to various types of sensor tests.

After rejecting several automated and manual scanning systems designed specifically for these tasks, we have designed and fabricated adaptive scanning hardware for use with an existing automated staging system. This system was originally designed for underwater ultrasonic tests.

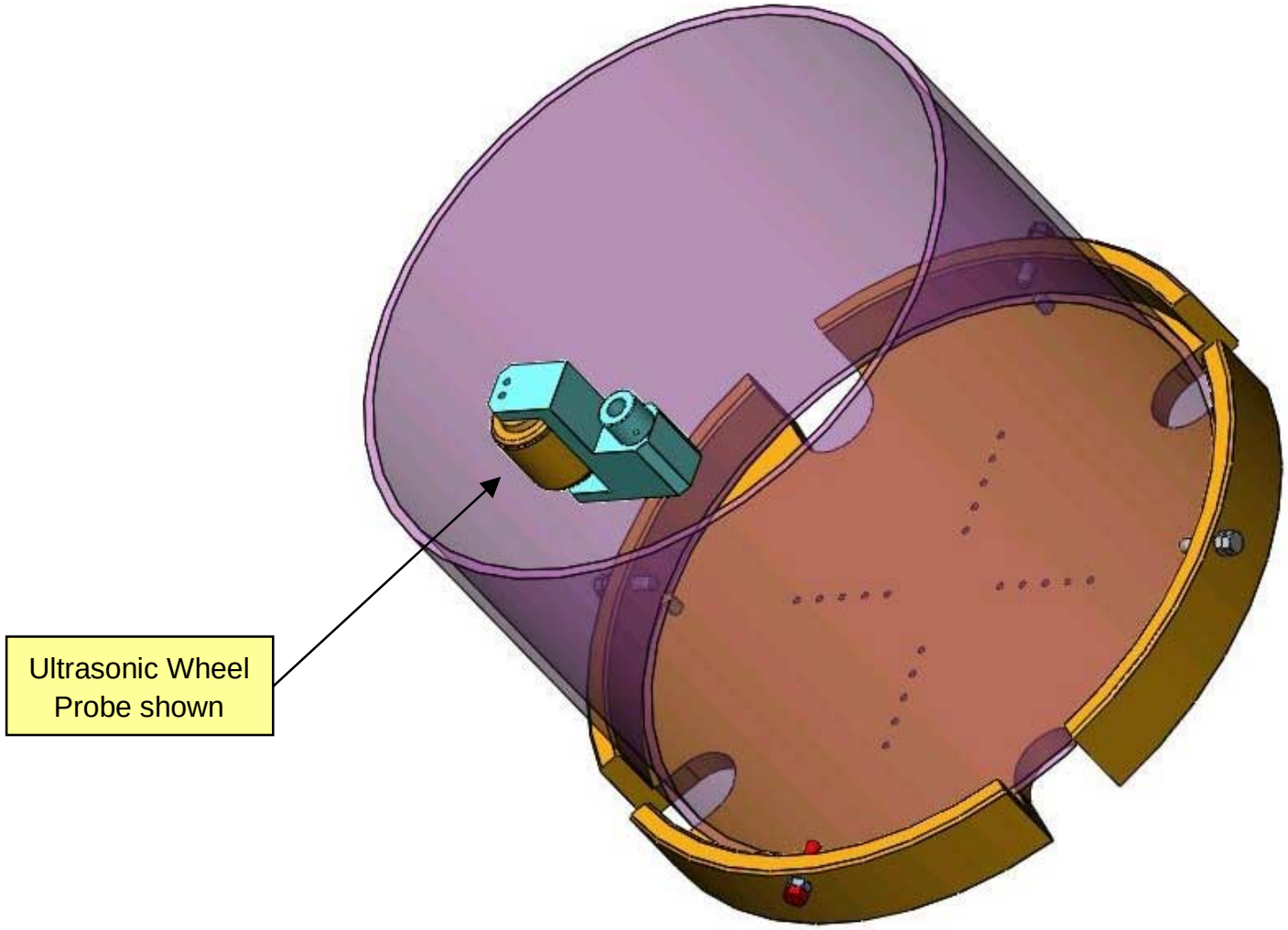
Also, analysis is under way to determine minimum damage or defect size that will need to be detected in our experiments.

Lab Based Scanning Platform





Adaptive Scanning Hardware for Sensor Evaluation Platform



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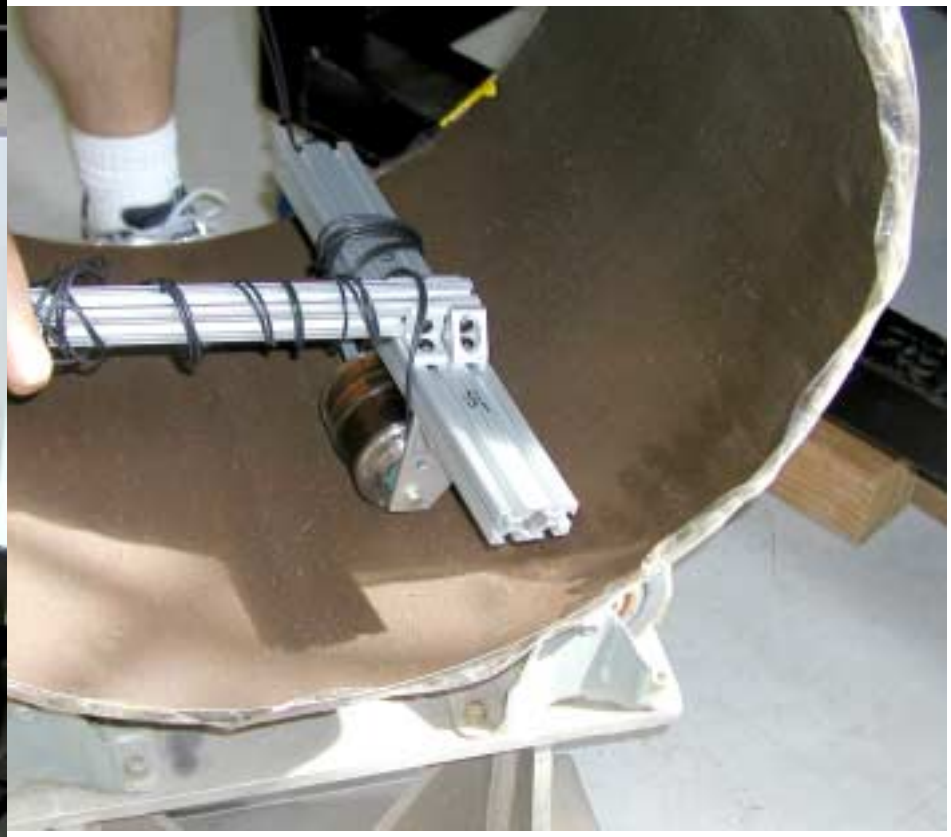
Ultrasonic Roller Probe Evaluation

- **Evaluating commercial transducers of different sizes and configurations, at different frequencies**
- **Have purchased and received 3” roller probe from Sigmatx for evaluation.**
- **Roller probe has 0 degree pitch/catch transducers, 45 degree side viewing transducer, and 45 degree forward looking transducer – all in single immersion wheel probe.**
- **Using reference samples with EDM notches and variable depth drill holes.**
- **Doing manual hand scans until scanning hardware is finished.**

Ultrasonic Roller Probe Evaluation



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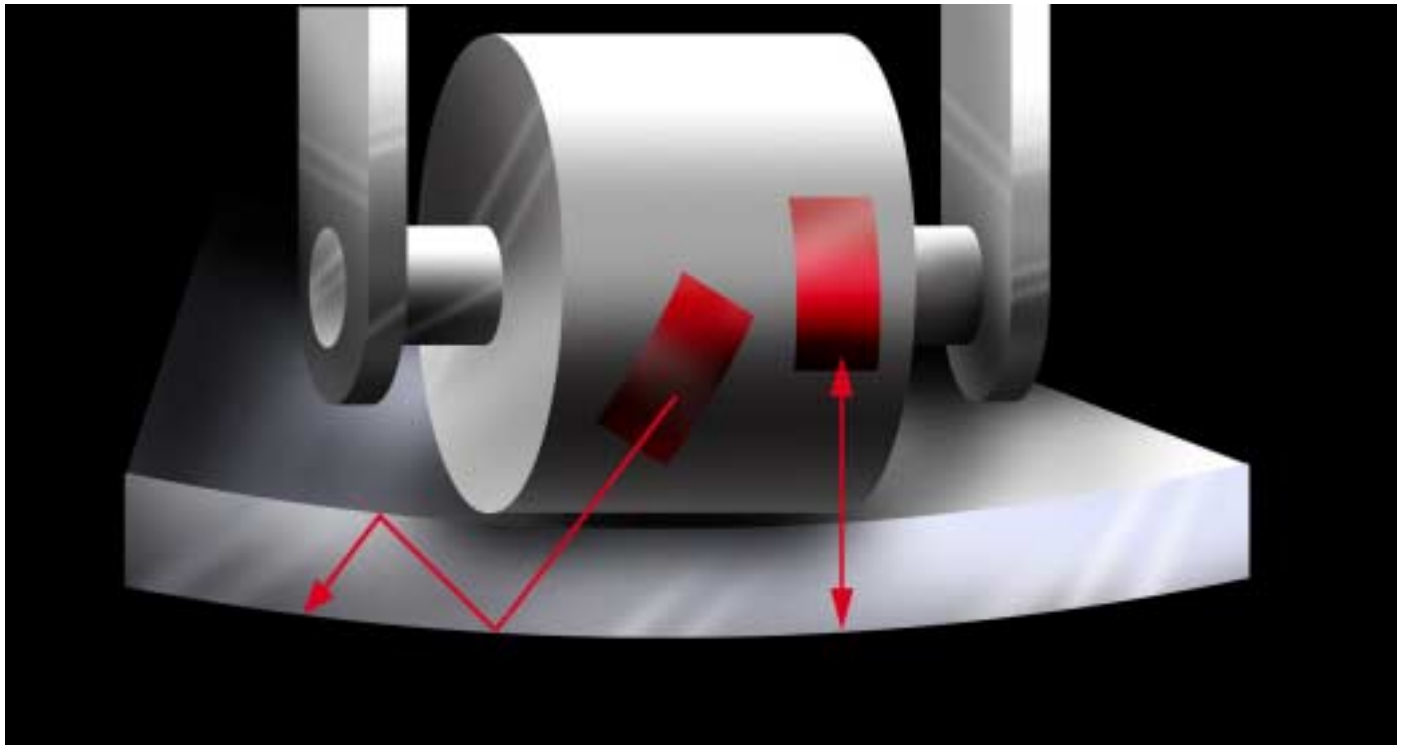
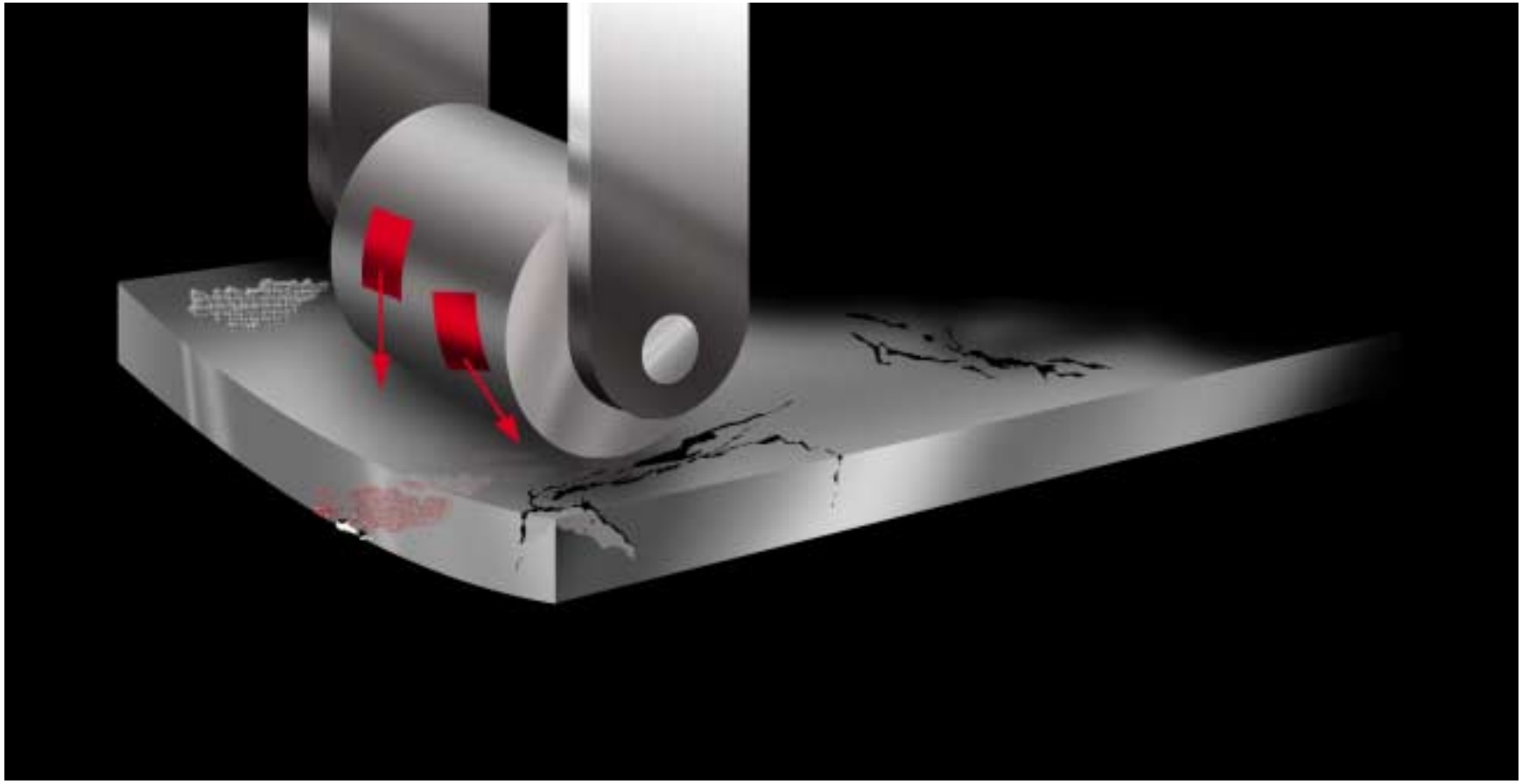
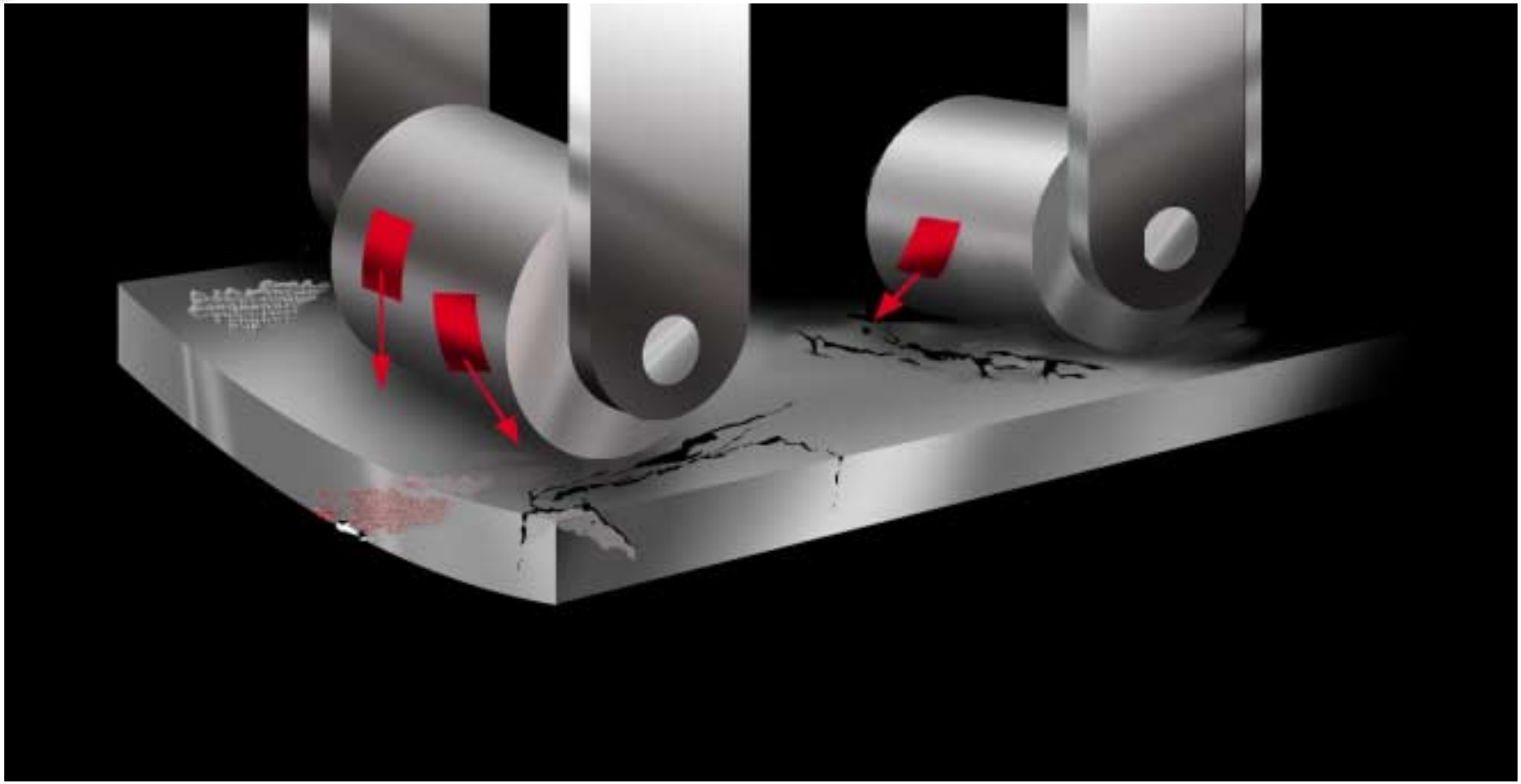
Typical UT Roller Probe



Single Array



Effective Dual Array



Ultrasonic To Do List

- Consider the interfacial requirements required by the robotic mechanism
  - Size / scaling
  - Power requirements / Minimization
  - Contact pressure optimization
  - Data recording / retrieval requirements
- Evaluate detection abilities at varying speeds

Eddy-Current Sensor Evaluation

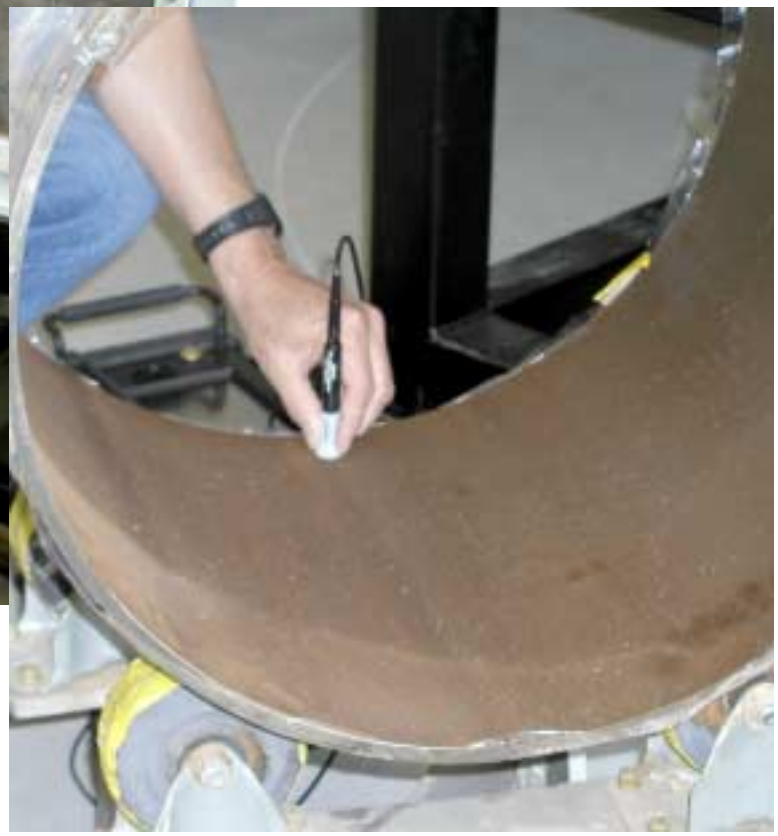
- **Evaluating absolute, reflective, and differential commercial probes of different sizes, at different frequencies**

- **Have wound several several reflection and differential probes for the evaluation**

- **Using reference samples with EDM notches and variable depth drill holes**

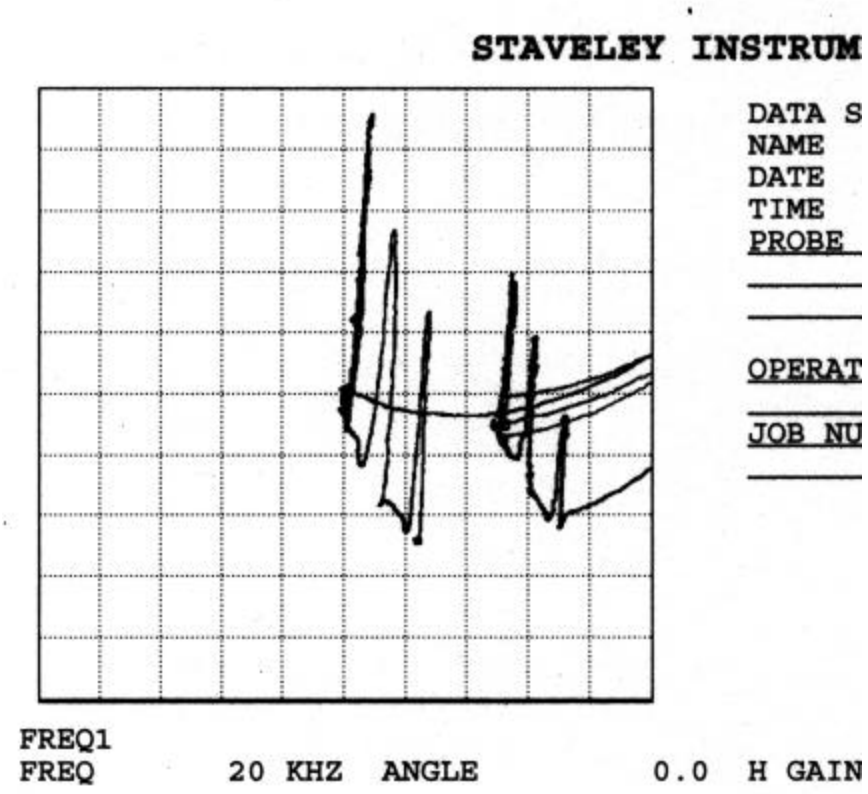
- **Doing manual hand scans until scanning hardware is finished**

Eddy Current Sensor Evaluation



Example Flaw Indications

Shown at the right is an example screen capture from our Staveley eddy-current instrument. The three spikes on the left are three surface holes at essentially zero liftoff. The three spikes on the right are the same holes but with a .030 inch liftoff. With this particular probe the flaw sensitivity is already off by about 50% at .030 inches lift-off.



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Observations to Date

- **Limited penetration, essentially surface only**
- **Reasonable crack sensitivity**
- **Reasonable background variation (noise) rejection possible**
- **Small probe required for high resolution, so many sensors (array) would be required for high speed**
- **Rapid loss of sensitivity with increased lift-off**

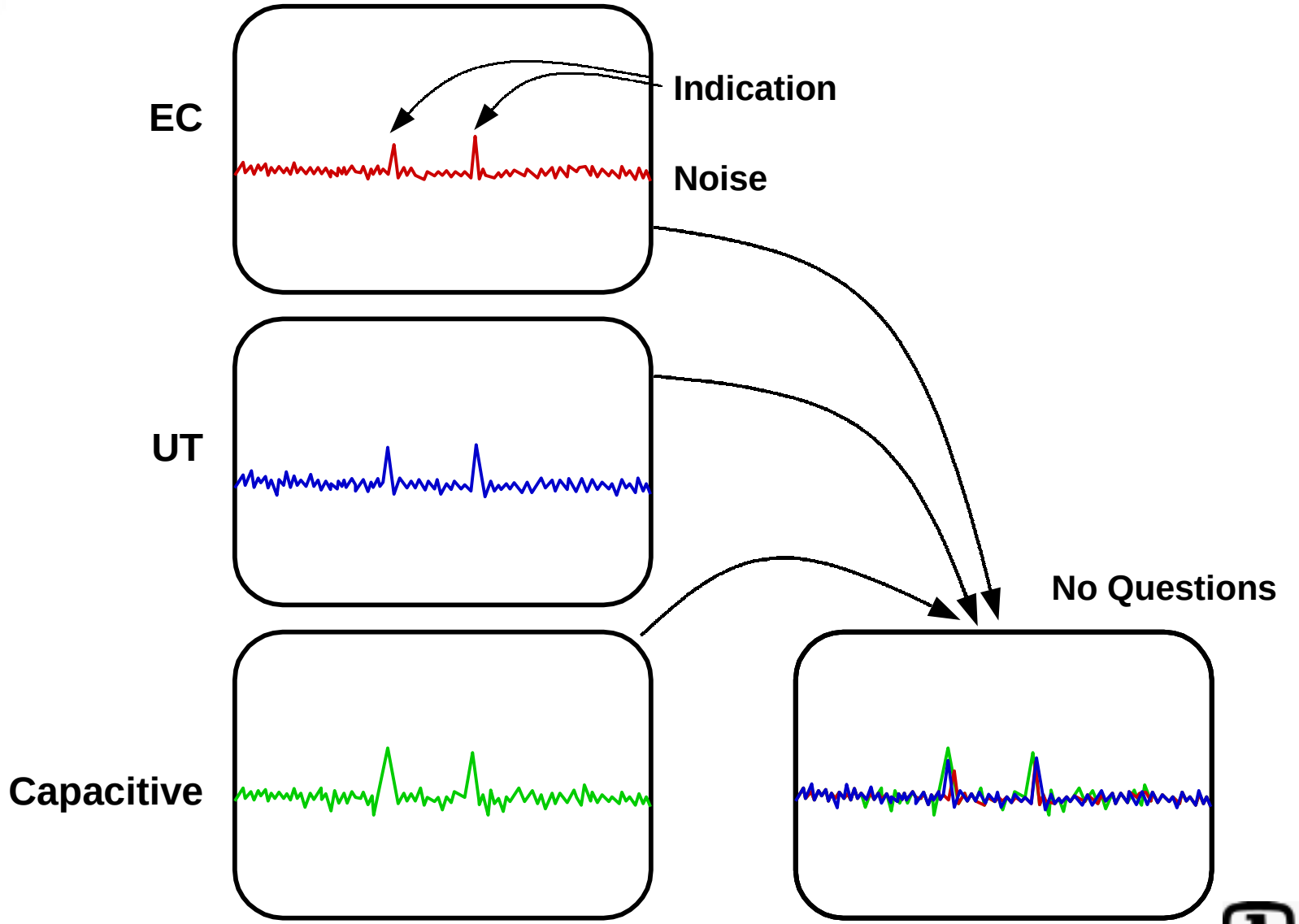
Eddy Current To Do List

- **Integrate EC system with scanning mechanism to yield 2-D plots**

- **Build an array probe and evaluate the electronics required to scan it**

- **Consider the interfacial requirements required by the robotic mechanism**

Sensor Marriage



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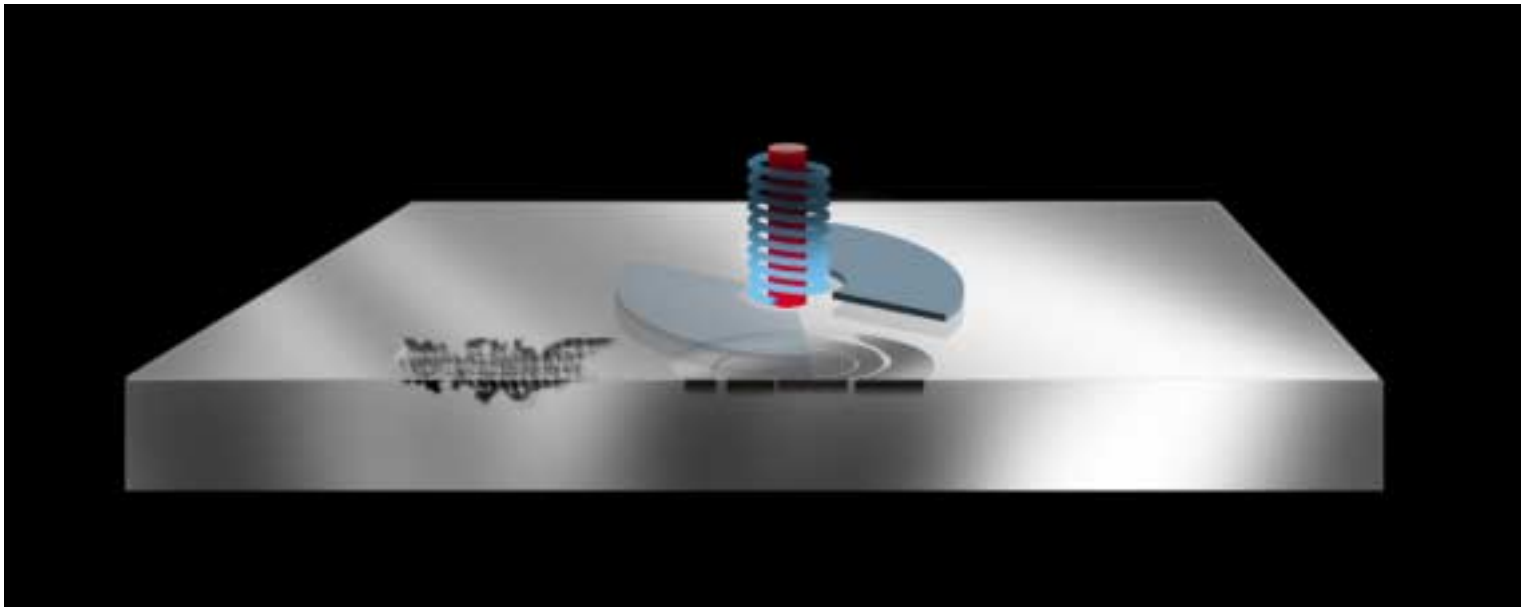
Eddy Current with Capacitive Sensor



Capacitive Sensor Demo

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